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THE BRITISH ASSOCIATION FOR THE  
ADVANCEMENT OF SCIENCE<sup>1</sup>

## FOSSILS AND LIFE

By Dr. F. A. BATHER

PRESIDENT OF THE GEOLOGICAL SECTION

FOR many a long year the relatively simple mechanics of the vertebrate skeleton have been studied by paleontologists and anatomists generally, and have been brought into discussions on the effect of use. The investigation of the mechanical conditions controlling the growth of organisms has recently been raised to a higher plane by Professor D'Arcy Thompson's suggestive book on "Growth and Form." These studies, however, have usually considered the structure of an animal as an isolated machine. We have to realize that an organism should be studied in relation to the whole of its environment, and here form comes in as distinct from structure. That mode of expression, though loose and purely relative, will be generally understood. By "form" one means those adaptations to the surrounding medium, to food, to the mode of motion, and so forth, which may vary with outer conditions while the fundamental structure persists. Though all structures may, conceivably, have originated as such adaptations, those which we call "form" are, as a rule, of later origin. Similar adaptive forms are found in organisms of diverse structure, and produce those similarities which we know as "convergence." To take but one simple instance from the relations of organisms to gravity. A stalked echinoderm naturally grows upright, like a flower, with radiate symmetry. But in the late Ordovician and in Silurian rocks are many in which the body has a curiously flattened leaf-like shape, in which the two faces are distinct, but the two sides alike, and in which this effect is often enhanced by paired outgrowths corresponding in shape if not in structure. Expansion of this kind implies a position parallel to the earth's surface, *i.e.*, at right angles to gravity. The leaf-like form and the balancers are adaptations to this unusual position. Recognition of this enables us to interpret the peculiar features of each genus, to separate the adaptive form from the modified struc-

<sup>1</sup> Extracts from addresses given at the Cardiff Meeting.

ture, and to perceive that many genera outwardly similar are really of quite different origin.

Until we understand the principles governing these and other adaptations—irrespective of the systematic position of the creatures in which they appear—we can not make adequate reconstructions of our fossils, we can not draw correct inferences as to their mode of life, and we can not distinguish the adaptive from the fundamental characters. No doubt many of us, whether paleontologists or neontologists, have long recognized the truth in a general way, and have attempted to describe our material—whether in stone or in alcohol—as living creatures; and not as isolated specimens but as integral portions of a mobile world. It is, however, chiefly to Louis Dollo that we owe the suggestion and the example of approaching animals primarily from the side of the environment, and of studying adaptations as such. The analysis of adaptations in those cases where the stimulus can be recognized and correlated with its reaction (as in progression through different media or over different surfaces) affords sure ground for inferences concerning similar forms of whose life-conditions we are ignorant. Thus Othenio Abel (1916) has analyzed the evidence as to the living squids and cuttle-fish and has applied it to the belemnites and allied fossils with novel and interesting results. But from such analyses there have been drawn wider conclusions pointing to further extension of the study. It was soon seen that adaptations did not come to perfection all at once, but that harmonization was gradual, and that some species had progressed further than others. But it by no means follows that these represent chains of descent. The adaptations of all the organs must be considered, and one seriation checked by another. Thus in 1890, in sketching the probable history of certain crinoids, I pointed out that the seriation due to the migration of the anal plates must be checked by the seriation due to the elaboration of arm-structure, and so on.

In applying these principles we are greatly helped by Dollo's thesis of the Irreversibility of Evolution. It is not necessary to regard this as an absolute Law, subject to no conceivable exception. It is a simple statement of the facts as hitherto observed, and may be expressed thus:

1. In the course of race-history an organism never returns exactly to its former state, even if placed in conditions of existence identical with those through which it has previously passed. Thus, if through adaptation to a new mode of life (as from walking to climbing) a race loses organs which were highly

useful to it in the former state, then, if it ever reverts to that former mode of (as from climbing to walking), those organs never return, but other organs are modified to take their place.

2. But (continues the Law), by virtue of the indestructibility of the past, the organism always preserves some trace of the intermediate stages. Thus, when a race reverts to its former state, there remain the traces of those modifications which its organs underwent while it was pursuing another mode of existence.

The first statement imposes a veto on any speculations as to descent that involve the reappearance of a vanished structure. It does not interfere with the cases in which old age seems to repeat the characters of youth, as in Ammonites, for here the old-age character may be similar, but obviously is not the same. The second statement furnishes a guide to the mode of life of the immediate ancestors, and is applicable to living as well as to fossil forms. It is from such persistent adaptive characters that some have inferred the arboreal nature of our own ancestors, or even of the ancestors of all mammals. To take but a single point, Dr. W. D. Matthew<sup>1</sup> finds traces of a former opposable thumb in several early Eocene mammals, and features dependent on this in the same digit of all mammals where it is now fixed.

#### THE STUDY OF HABITAT

The natural history of marine invertebrates is of particular interest to the geologist, but its study presents peculiar difficulties. The marine zoologist has long recognized that his early efforts with trawl and dredge threw little light on the depth in the sea frequented by his captures. The surface floaters, the swimmers of the middle and lower depths, and the crawlers on the bottom were confused in a single haul, and he has therefore devised means for exploring each region separately. The geologist, however, finds all these faunas mixed in a single deposit. He may even find with them the winged creatures of the air, as in the insect beds of Gurnet Bay, or the remains of estuarine and land animals.

Such mixtures are generally found in rocks that seem to have been deposited in quiet land-locked bays. Thus in a Silurian rock near Visby, Gotland, have been found creatures of such diverse habitat as a scorpion, a possibly estuarine *Pterygotus*, a large barnacle, and a crinoid of the delicate form usually associated with clear deep water. The lagoons of Solenhofen have preserved a strange mixture of land and sea life,

<sup>1</sup> 1904, *Amer. Natural.*, XXXVIII., 813.

without a trace of fresh or brackish water forms. *Archaeopteryx*, insects, flying reptiles, and creeping reptiles represent the air and land fauna; jelly-fish and the crinoids *Saccocoma* are true open-water wanderers; sponges and stalked crinoids were sessile on the bottom; starfish, sea-urchins, and worms crawled on the sea-floor; king-crabs, lobsters, and worms left their tracks on mud-flats; cephalopods swam at various depths; fishes ranged from the bottom mud to the surface waters. The Upper Ordovician Starfish bed of Girvan contains not only the crawling and wriggling creatures from which it takes its name, but stalked echinoderms adapted to most varied modes of life, swimming and creeping trilobites, and indeed representatives of almost all marine levels.

In the study of such assemblages we have to distinguish between the places of birth, of life, of death, and of burial, since, though these may all be the same, they may also be different. The echinoderms of the Starfish bed further suggest that closer discrimination is needed between the diverse habitats of bottom forms. Some of these were, I believe, attached to sea-weed; others grew up on stalks above the bottom; others clung to shells or stones; others lay on the top of the sea-floor; others were partly buried beneath its muddy sand; others may have groveled beneath it, connected with the overlying water by passages. Here we shall be greatly helped by the investigations of C. G. J. Petersen and his fellow-workers of the Danish Biological Station.<sup>2</sup> They have set an example of intensive study which needs to be followed elsewhere. By bringing up slabs of the actual bottom, they have shown that, even in a small area, many diverse habitats, each with its peculiar fauna, may be found, one superimposed on the other. Thanks to Petersen and similar investigators, exact comparison can now take the place of ingenious speculation. And that this research is not merely fascinating in itself, but illuminatory of wider questions, follows from the consideration that analysis of faunas and their modes of life must be a necessary preliminary to the study of migrations and geographical distribution.

#### THE TEMPO OF EVOLUTION

We have not yet done with the results that may flow from an analysis of adaptations. Among the many facts which, when considered from the side of animal structure alone, lead to transcendental theories with Greek names, there is the observa-

<sup>2</sup> See especially in his summary, "The Sea Bottom and its Production of Fish Food," Copenhagen, 1918.

tion that the relative rate of evolution is very different in races living at the same time. Since their remains are found often side by side, it is assumed that they were subject to the same conditions, and that the differences of speed must be due to a difference of internal motive force. After what has just been said you will at once detect the fallacy in this assumption. Professor Abel has recently maintained that the varying tempo of evolution depends on the changes in outer conditions. He compares the evolution of whales, sirenians, and horses during the Tertiary Epoch, and correlates it with the nature of the food. Roughly to summarize, he points out that from the Eocene onwards the sirenians underwent a steady, slow change, because, though they migrated from land to sea, they retained their habit of feeding on the soft water-plants. The horses, though they remained on land, display an evolution at first rather quick, then slower, but down to Pliocene times always quicker than that of the sirenians; and this is correlated with their change into eaters of grain, and their adaptation to the plains which furnish such food. The whales, like the sirenians, migrated at the beginning of the Tertiary from land to sea; but how different is their rate of evolution, and into what diverse forms have they diverged! At first they remained near the coasts, keeping to the ancestral diet, and, like the sirenians, changing but slowly. But the whales were flesh-eaters, and soon they took to hunting fish, and then to eating large and small cephalopods; hence from the Oligocene onwards the change was very quick, and in Miocene times the evolution was almost tempestuous. Finally, many whales turned to the swallowing of minute floating organisms, and from Lower Pliocene times, having apparently exhausted the possibilities of ocean provender, they changed with remarkable slowness.

Whether such changes of food or of other habits of life are, in a sense, spontaneous, or whether they are forced on the creatures by changes of climate and other conditions, makes no difference to the facts that the changes of form are a reaction to the stimuli of the outer world and that the rate of evolution depends on those outer changes.

Whether we have to deal with similar changes of form taking place at different times or in different places, or with diverse changes affecting the same or similar stocks at the same time and place, we can see the possibility that all are adaptations to a changing environment. There is then reason for thinking that ignorance alone leads us to assume some inexplicable force urging the races this way or that, to so-called advance or to apparent degeneration, to life or to death.

## THE RHYTHM OF LIFE

The comparison of the life of a lineage to that of an individual is, up to a point, true and illuminating; but when a lineage first starts on its independent course (which really means that some individuals of a pre-existing stock enter a new field), then I see no reason to predict that it will necessarily pass through periods of youth, maturity, and old age, that it will increase to an acme of numbers, of variety, or of specialization, and then decline through a second childhood to ultimate extinction. Still less can we say that, as the individuals of a species have their allotted span of time, long or short, so the species or the lineage has its predestined term. The exceptions to those assertions are indeed recognized by the supporters of such views, and they are explained in terms of rejuvenescence, rhythmic cycles, or a grand despairing outburst before death. This phraseology is delightful as metaphor, and the conceptions have had their value in promoting search for confirmatory or contradictory evidence. But do they lead to any broad and fructifying principle? When one analyses them one is perpetually brought up against some transcendental assumption, some unknown entelechy that starts and controls the machine, but must forever evade the methods of our science.

The facts of recurrence, of rhythm, of rise and fall, of marvelous efflorescences, of gradual decline, or of sudden disappearances, all are incontestable. But if we accept the intimate relation of organism and environment, we shall surmise that on a planet with such a geological history as ours, with its recurrence of similar physical changes, the phenomena of life must reflect the great rhythmic waves that have uplifted the mountains and lowered the deeps, no less than every smaller wave and ripple that has from age to age diversified and enlivened the face of our restless mother.

To correlate the succession of living forms with all these changes is the task of the paleontologist. To attempt it he will need the aid of every kind of biologist, every kind of geologist. But this attempt is not in its nature impossible, and each advance to the ultimate goal will, in the future as in the past, provide both geologist and biologist with new light on their particular problems. When the correlation shall have been completed, our geological systems and epochs will no longer be defined by gaps in our knowledge, but will be the true expression of the actual rhythm of evolution. Lyell's great postulate of the uniform action of nature is still our guide; but we have ceased to confound uniformity with monotony. We return,

though with a difference, to the conceptions of Cuvier, to those numerous and relatively sudden revolutions of the surface of the globe which have produced the corresponding dynasties in its succession of inhabitants.

#### THE FUTURE

The work of a systematic paleontologist, especially of one dealing with rare and obscure fossils, often seems remote from the thought and practice of modern science. I have tried to show that it is not really so. But still it may appear to some to have no contact with the urgent problems of the world outside. That also is an error. Whether the views I have criticized or those I have supported are the correct ones is a matter of practical importance. If we are to accept the principle of predetermination, or of blind growth-force, we must accept also a check on our efforts to improve breeds, including those of man, by any other means than crossing and elimination of unfit strains. In spite of all that we may do in this way, there remain those decadent races, whether of ostriches or human beings, which "await alike the inevitable hour." If, on the other hand, we adopt the view that the life-history of races is a response to their environment, then it follows, no doubt, that the past history of living creatures will have been determined by conditions outside their control, it follows that the idea of human progress as a biological law ceases to be tenable; but, since man has the power of altering his environment and of adapting racial characters through conscious selection, it also follows that progress will not of necessity be followed by decadence; rather that, by aiming at a high mark, by deepening our knowledge of ourselves and of our world, and by controlling our energy and guiding our efforts in the light of that knowledge, we may prolong and hasten our ascent to ages and to heights as yet beyond prophetic vision.

#### HEREDITY

By Miss E. R. SAUNDERS

PRESIDENT OF THE BOTANICAL SECTION

BY the term Inheritance we are accustomed to signify the obvious fact of the resemblance displayed by all living organisms between offspring and parents, as the direct outcome of the contributions received from the two sides of the pedigree at fertilization: to indicate, in fact, owing to lack of knowledge of the workings of the hereditary process, merely the *visible*